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ORIGINAL PAPER

Structure and regeneration status of Komto Afromontane moist forest, East Wollega Zone, west Ethiopia

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Abstract: We conducted a study in Komto Forest in East Wollega Zone, Oromia National Regional State, West Ethiopia for determining vegetation structure and regeneration status in this forest. We systematically sampled 53 quadrats (20 m × 20 m) along line transects radiating from the peak of Komto Mountain in eight directions. Vegetation parameters such as DBH, height, seedling and sapling density of woody species, and location and altitude of each quadrat were recorded. In total, 103 woody plant species of 87 genera and 45 families were identified. Analysis of selected tree species revealed different population structures. Generally, the forest was dominated by small trees and shrubs characteristic of secondary regeneration. Observations on the regeneration of the forest indicated that there are woody species that require urgent conservation measures. Based on the results of this study, we recommend detailed ecological studies of various environmental factors such as soil type and properties, and ethnobotanical studies to explore indigenous knowledge on uses of plants.

Keywords: East Wollega; Komto Forest; moist montane forest; regeneration status; structural analysis

Introduction

Ethiopia possesses a large and diverse resource of plants and wildlife due to the extreme variation in climate and terrain. FAO (1996) stated that Ethiopia is one of the African countries known for high endemism of wild plant and animal species. In addition, because of her long history of agriculture and diversity of environments, Ethiopia is one of 12 Vavilov centers of crop genetic diversity (Woldu 2008; KiKitessa et al. 2008). Ethiopia has over 300 tree species, which are used for construction and industrial purposes.

Ethiopian forests and woodlands are repositories and gene banks for several domesticated and/or important wild plants and wild relatives of domesticated plants. For example, coffee (*Coffea arabica* L.) is found in the wild in the moist evergreen montane forests of the south, west, and southwest of the country. Forests are important not only for the products that can be harvested from them but also for preventing erosion and for affecting the climate in a positive way (NBSAP 2005).

Many scholars have studied and described Ethiopian vegetation. Based on their results, the vegetation types of Ethiopia have been grouped into eight general categories. These are Desert and Semi-desert Scrubland, *Acacia-Commiphora* Woodland, Moist Evergreen Montane Forest, Lowland Semi-evergreen Forest, *Combertum-Terminalia* Woodland, Dry Evergreen Montane Forest, Afroalpine, and Sub-Afroalpine Vegetation, and Riparian and Wetland Vegetation (Kelbessa et al. 1992; Demissew et al. 1996; Friis et al. 2001; Demissew et al. 2004; Demissew and Friis 2009; Zerihun et al. 1989).

Afromontane forests in Ethiopia are generally cooler and more humid than the surrounding lowland although the classification of forests as “moist” or “dry” and the criteria followed to define these limits are loose. Logan (1946) used altitudinal variations to distinguish between what he called ‘climatic moist woodland’ and ‘climatic dry woodland’ on the Ethiopian plateau (Bekele 1994). Characteristic species in Afromontane area of Ethiopia include *Podocarpus falcatus*, *Prunus africana*, *Hagenia abyssinica, Juniperus procera,* and *Olea* sp.

The moist Evergreen Montane Forest comprises the humid forest in the southeastern plateau, Harenna Forest, (Lissanework et al. 1989) and Mana Angetu Forest (Lulekal et al. 2008) and high forests of the country mainly the southwest forests. Several researchers have studied the composition and structure of this forest vegetation type in southern, southwest and western part of the country and described them on floristic basis (Lisanework et al. 1989; Woldu et al. 2008; Yeshitela and Bekele 2002; Kelbessa

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and soromessa 2008). The Moist Evergreen Montane Forest of west and southwest Ethiopia occurs between 1,500–2,500 m a.s.l. in Wollega, Illubabor and Kefa. The average annual temperature and rainfall of this vegetation type is 18–20°C, and 1,500 and 2,000 mm, respectively. The maximum rainfall is from April to October (Friis et al. 1982; Friis 1992)

Moist evergreen montane forest ecosystem is the most diverse ecosystem in composition, structure and habitat types (NBSAP 2005). The common species in this forest include *Pouteria altissima*, *Pouteria adolfi-friederici*, *Trilepsium madagascariense*, *Morus mesozygia*, *Mimusops kummel*, *Podocarpus falcatus*, *Coffea arabica*, *Galiniera saxifraga*, *Syzygium guineense* ssp. *afromontanum*, *Apodytes dimidiata*, *Prunus africana*, *Albizia gummifera*, *Albizia schimperiana*, *Croton macrostachyus*, *Cassipourea malosana*, *Ekebergia capensis*, *Euphorbia ampliphylla*, *Ficus sur*, *Maesa lanceolata*, *Teclea nobilis* and *Bersama abyssinica* (EFAP 1994; FAO 1996; NBSAP 2005; Senbeta and Denich 2006; Kelbessa and Soromessa et al. 2008).

About 35%–40% of the land area of Ethiopia was covered by forest vegetation in the 1990s (EFAP 1994). Since then, forests have been destroyed at an alarming rate and the area covered by forests by 1998 was only 2.4 percent (EPA 1998). Factors such as rising demand for timber products, conversion of forest land to agricultural land, and expanding population pressure are responsible for the decline in the forest cover of the country (EPA 1998; USAID 2008).

Even though Ethiopia is rich in biodiversity with high endemism and most of her forests have provided socio-economic benefits and ecological functions for long periods of time, many species are now being threatened or are endangered or locally extinct. This is due to habitat destruction and fragmentation, and over-exploitation of wildlife and habitats (Teketay 2001). Understanding natural regeneration of plant communities requires information on soil seed banks and/or seedling banks, and quantity and quality of seed rain and durability of seeds in the soil (Teketay 2005).

Komto Forest was proposed as a Forest reserve area in 1976 and demarcated as a state forest in 1990 as one of the 58 National Forest Priority areas (NFPA), (EFAP 1994). Though the Forest has been under protection since its demarcation, it has been continuously exploited by surrounding people for agricultural land expansion, timber harvesting, firewood collection and charcoal production, woodcutting for construction and other purposes. Little is known about the forest, as there is no floristic and structural study was made before. Thus, the present study has the following objectives: (1) to analyze the structure of the forest, (2) to determine the regeneration status of some woody species, and (3) to assess the status of the vegetation and to make some recommendations on the management and conservation of the forest.

Materials and methods

Study area

The forest covers an area of about 500 ha at latitudes 9°05.10′–9°06.35′ N and longitude 036°36.47′–036°38.10′ E (Fig. 1). Elevations range from 2,100 to 2,482 m a.s.l. on Komto Mountain

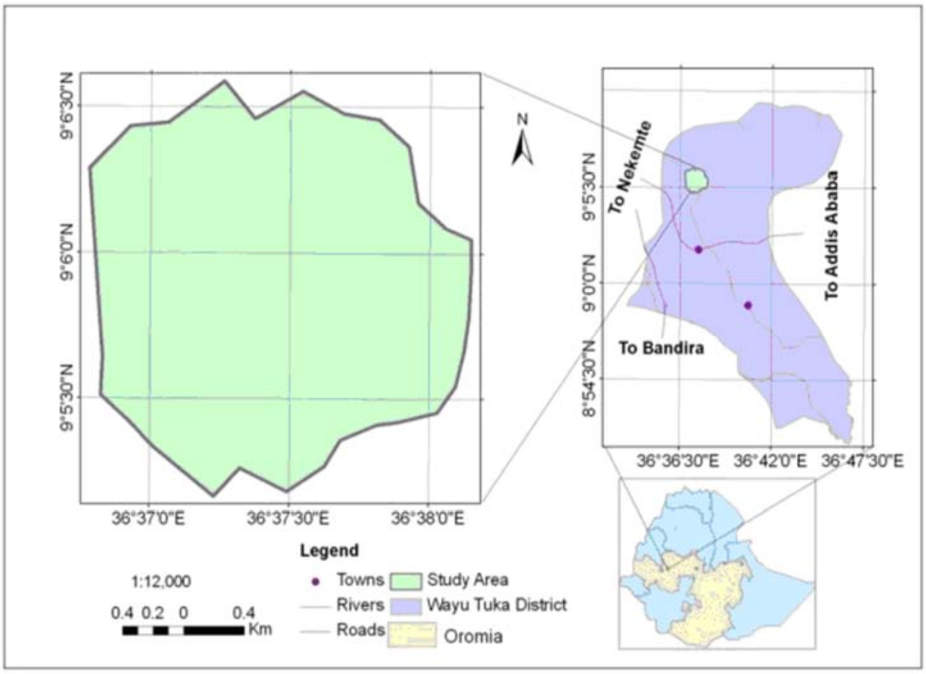

Fig. 1 Location map of the study forest

The rainfall and temperature data for this study were collected from the nearest Meteorological Station, Nekemte, which is

about 12 km away from the capital of Wayu Tuka District. Data were collected from 1998–2007 by National Meteorological Service Agency. Climate diagram was computed by using R for window version 2.10.1 statistical package (R-Development Core Team 2007). The area falls within the southwestern and western unimodal rainfall regions of Ethiopia. Generally, the study area is humid and moderately hot. The mean annual temperature is about 18.8°C, and the mean minimum and maximum temperatures are 12.2°C and 27.9°C, respectively. The hottest months are from February to October with maximum temperature record in February and May (27.9°C) and the coldest months are November to January with minimum temperature of 12.2°C in December and January (Fig. 2). The mean annual rainfall of the study area is 2,067 mm. The rainfall pattern is unimodal, with little or no rainfall in January and February, gradually increasing to a peak between May and October, and decreasing in November and December (Fig. 2).

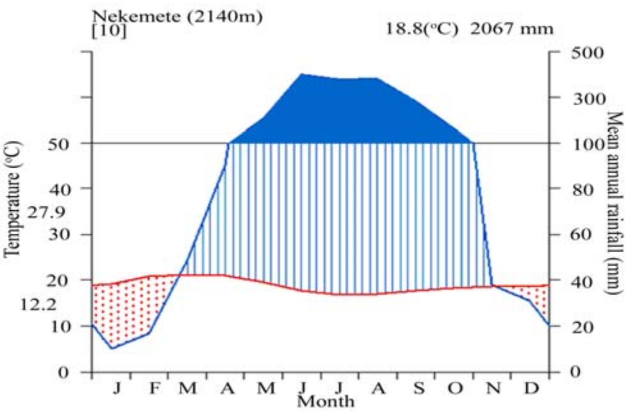

Fig. 2 Climatic diagram of Nekemte Town (1998–2007)

Vegetation of the study area (eastern highlands of Wollega) is broad-leaved and evergreen moist forests with important tree species including *Outeria adolfi-friederici*, *Syzygium guineense* ssp. *afromontanum*, *Apodytes dimidiata*, *Prunus africana*, *Albizia gummifera*, *Albizia schimperiana*, *Croton macrostachyus*, *Cassipourea malosana*, *Ekebergia capensis*, *Euphorbia ampliphylla*, *Ficus sur*, *Maesa lanceolata*, *Teclea nobilis*, and *Bersama abyssinica* (Teketay 2005).

Degradation of the high forest led to formation of bushland and farmland (personal observation and communication with inhabitants of the area). Komto Forest hosts wild animals including spotted hyena, abyssinian black and white colobus monkey, common jackal, blue monkey, bushbuck, common duiker, aardvark, olive baboon, hare, vervet monkey, and crested porcupine. The wildlife, similar to the forest, is severely threatened by deforestation and habitat fragmentation due to human encroachment.

Reconnaissance survey, sampling design and data collection

Systematic sampling methods followed Kent and Coker (1992) and Muller-Dombois and Ellenberg (1974). Sampling quadrats were arranged along transects in eight (E, NE, N, NW, W, SW, S, SE) directions from the peak of Mount Komto to its base and onto the surrounding plain. Quadrats covered variations in aspect and slope and included one quadrat at the top of the mountain. Along the eight transects we set 20 m × 20 m (400 m^2) sampling quadrats at intervals of 200 m. The numbers of quadrats/transect varied depending on the length of each transect. A total of 53 quadrats were sampled. Five 5 m × 5 m sub plots, one at each corner and one at the center of the main quadrat were set to sample shrubs. We sampled from October 15 to November 25, 2009. A complete list of trees, shrubs, and lianas was made from the systematically selected quadrats along each transect. Specimens of all woody plant taxa were collected, pressed, dried and brought to the National Herbarium (ETH), Addis Ababa University for identification and storage. Nomenclature followed Flora of Ethiopia and Eritrea (FEE).

In each plot, diameter and height were recorded for all woody plants. Diameter was measured for all individual trees and shrubs having DBH (Diameter at Breast Height) greater than 2.5 cm. If the tree branched at breast height or below, the diameter was measured separately for the branches and averaged. Trees and shrubs with DBH less than 2.5 cm were counted. Height was measured for individual trees and shrubs with DBH greater than 2.5 cm using Suunto Height Meter and calibrated stick. Where topographic features made it difficult to measure trees and shrubs, height was estimated visually. We calculated seedling and sapling densities and regeneration of selected species within the same quadrats. We partitioned the major quadrats (400 m^2) into four, each 100 m^2 (10 m × 10 m), to ease the counting of seedlings. In each 100 m^2 quadrat, we counted all seedlings less than 1 m in height. Individuals attaining 1 m and above with DBH less than 2.5 cm were considered as saplings and counted. Environmental variables such as altitude and geographical coordinates were also measured for each plot using Garmin 72 Geographical Position System (Kent et al. 1992).

Structural data analysis

The importance value index compares the ecological significance of species. Species with the greatest importance value are dominant in the forest. Importance value indices (IVI) were computed for dominant woody species based on their relative density (R_D), relative dominance (R_{DO}) and relative frequency (R_F) as follows (Kent et al. 1992):

$$I_{VI} = R_D + R_{DO} + R_F \tag{1}$$

where, R_D is the number of all individuals of a species/the total number of all individuals (DBH > 2.5 cm) × 100; R_F is the number of plots where a species occurs/ the total occurrence of all species in all of the plots × 100. R_{DO} is Dominance of a species/Dominance of all species × 100 (DBH > 2.5 cm) and Dominance is mean basal area/tree × the number of trees of a species.

Basal area provides a better measure of the relative importance of the species than does a stem count (Cain et al. 1959; Tamirat 1994). Basal area (B_A) was calculated using DBH as follows:

$$B_A = \pi d^2 / 4 \quad (2)$$

where, π= 3.14; d is DBH (m).

The structure of the vegetation was described using frequency distributions of DBH, height and IVI. Tree or shrub density and basal area values were computed per hectare. The vertical structure of the woody species occurring in the Komto Forest was analyzed using the IUFRO classification scheme. This scheme categorizes a vertical structure of vegetation into upper, middle and lower storey. The population structures of some selected species were also analyzed for the interpretation of the pattern of population dynamics in the forest.

Results

We recorded 103 woody plant species of 87 genera and 45 families in Komto Forest (Appendix I). Of these, 42 species are trees, 43 species are shrubs, 17 species are lianas, and 1 species is a woody hemi-parasite. Fabaceae and Malvaceae were the most dominant families, contributing 12 species and 8 species to the total, respectively. These families were followed by Celestraceae with 6 and Euphorbiaceae with 5 species. The remaining 41 families contributed four or fewer species.

Tree and shrub density

Density of trees and shrubs with DBH greater than 2.5 cm was 952.83 individuals·ha^{-1}. Density of trees and shrubs with DBH 10–20 cm was 330 individuals·ha^{-1}. Density of trees and shrubs with DBH greater than 20 cm was 215 individuals·ha^{-1} (Table 1). The ratio described as a/b, is taken as the measure of size class distribution. Accordingly, the ratio of individuals with DBH 10–20 cm (a) to DBH > 20 cm (b) was 1.53.

Table 1. Density of trees and shrubs by DBH class

DBH (cm)	No. of individuals (ha^{-1})	Percentage (%)
2.5-10.0	408.02	42.82
10.1-20.0	330.00	34.61
>20.0	215.00	22.57
Total	952.83	100

Comparison of tree and shrub densities with DBH 10–20 cm (a), DBH > 20 cm (b) and the ratio (a/b) for Komto Forest with ten other forests in Ethiopia is given in Table 2. The a/b ratio at Komto Forest was lower than at Alata-Bolale, Menagesha Suba, Chilimo, and Masha Anderacha, but higher than at Dodola Forest (Table 2).

Height class distributions

The frequency distribution of height classes of trees and shrubs in Komto Forest is given in Fig. 3. More than 65% of trees and shrubs were less than 9 m tall (Height classes 1 and 2). Only a small proportion, about 24%, reached a height of 15 m and above indicating dominance by shorter plants.

Table 2. Comparisons of tree and shrub densities with DBH 10−20 cm (a) and tree density with DBH > 20 cm (b) from Komto Forest with 10 other forests in Ethiopia

Forests	Density (a)	Density (b)	Ratio a/b	Sources
Alata-Bolale	365	219	1.67	Woldeyohannes 2008
Chilimo	638	250	2.55	Bekele 1994
Dindin	437	219	2.00	Shibru and Balcha. 2004
Dodola	521	351	1.48	Hundera et al. 2007
Donkoro	526	285	1.85	Ayalew et al. 2006
Gura Ferda	500	263	1.90	Denu 2006
Masha Andaracha	385.7	160.5	2.40	Yeshitela et al. 2003
Menagesha Suba	484	208	2.33	Bekele 1993
Menna Angetu	292	139	2.10	Lulekal 2008
Wof Washa	329	215	1.53	Bekele 1993
Komto	**330**	**215**	**1.53**	**Present study**

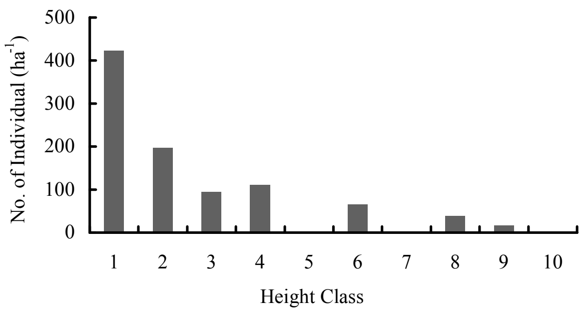

Fig. 3 Height classes versus relative density ha^{-1} in Komto Forest (Tree species are classified according to different height classes, such as, 1 stands for 2.6–6.0 m, 2 stands for 6.1–9.0 m, 3 stands for 9.1–12.0 m, 4 stands for 12.1–15.0 m, 5 stands for 15.1–18.0 m, 6 stands for 18.1–21.0 m, 7 stands for 21.1–24.0 m, 8 stands for 24.1–27.0 m, 9 stands for 27.1–30.0 m and 10 stands for >30.0m).

DBH class distribution

DBH distribution of the woody species is given in Fig. 4. As DBH increased, the number of individuals decrease beginning from 548.58 stems·ha^{-1} in the first class down to 12.73 stems·ha^{-1} in the last DBH class. The distribution curve was a regular inverted J-shaped distribution of individuals across the DBH classes.

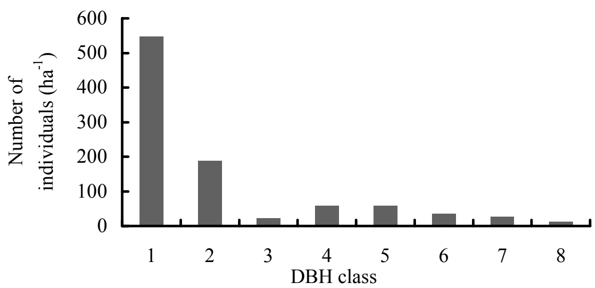

Fig. 4 DBH class versus the number of individuals per hectare. (Tree species are classified according to different DBH classes, such as, 1 stands for 2.6–12.0 cm of DBH, 2 stands for 12.1–22.0 cm, 3 stands for 22.1–32.0 cm, 4 stands for 32.1–42.0 cm, 5 stands for 42.1–52.0 cm, 6 stands for 52.1–62.0 cm, 7 stands for 62.1–72.0 cm and 8 stands for ≥72.0 cm).

Basal area

Species with the largest contribution in basal area can be considered the most important woody species in the forest. Total basal area for Komto Forest was 50.72 $m^2 \cdot ha^{-1}$. The contribution of each DBH class to the total basal area is presented in Table 3 and Fig. 5.

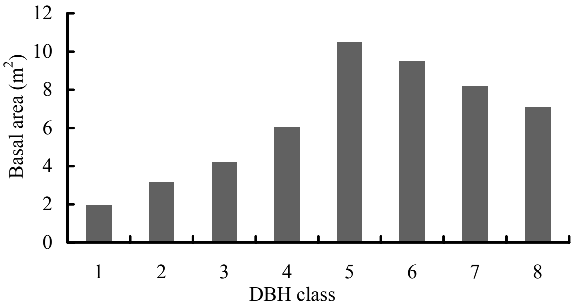

Fig. 5 Basal area distribution over DBH classes of Komto Forest

Table 3 shows that 57% of all individuals had DBH less than 12 cm (DBH class 1). The percentage contribution of this class to the total basal area, however, was only 3.87%. Conversely, individuals in the DBH classes greater than 42 cm had a density of about 14% of the total, but they accounted for about 69.64% of the total basal area of the Forest.

Table 3. Contribution of different DBH classes to the total density and basal area per hectare in Komto Forest

DBH Classes	Density		Basal area	
	Number of Stem	Percentage (%)	Area (m^2)	Percentage (%)
1	548.58	57.57	1.966	3.87
2	189.15	19.85	3.2	6.31
3	21.69	2.27	4.2	8.28
4	58.98	6.19	6.03	11.89
5	58.49	6.14	10.51	20.72
6	35.38	3.71	9.51	18.75
7	27.83	2.92	8.2	16.17
8	12.73	1.34	7.1	14.00
Total	952.83	99.98	50.716	99.99

Notes: DBH class 1 stands for 2.6–12.0 cm, 2 stands for 12.1–22.0 cm, 3 stands for 22.1–32.0 cm, 4 stands for 32.1–42.0 cm, 5 stands for 42.1–52.0 cm, 6 stands for 52.1–62.0 cm, 7 stands for 62.1–72.0 cm and 8≥72.0 cm.

The basal area of Komto Forest was greater than that of Menagesha Suba, Chilimo, and Denkoro Forests (Abate et al. 2006), and comparable with that at Jibat (Bekele 1993) and Dindin Forests (Shibru and Balcha 2004). Komto had less basal area than did Alata-Bolale Forest (Woldeyohannes 2008), Gendo Forest, Masha-Anderacha Forest (Yeshitela and Bekele 2003) and Wof-Washa Forest (Bekele 1993), (Fig. 6).

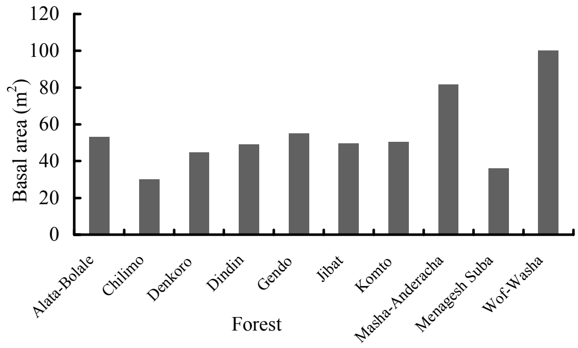

Fig. 6 Basal area (m^2) of different forests in Ethiopia

Vertical structure

The IUFRO classification scheme classifies the storey into upper, where the tree height is greater than 2/3 of the top height; middle, where the tree height is in between 1/3 and 2/3 of the top height and the lower storey where the tree height is less than 1/3 of the top height. The top height for trees in Komto Forest was 40 m. The tree species that occupied the upper storey in Komto Forest included *Croton macrostachyus*, *Prunus africana*, *Pouteria adolfi-friederici*, *Ficus sur*, *Schefflera abyssinica*, *Euphorbia ampliphylla*. In addition, only few individuals attained the upper storey as the ratio of individuals to species is lower (Fig. 7 & Table 4).

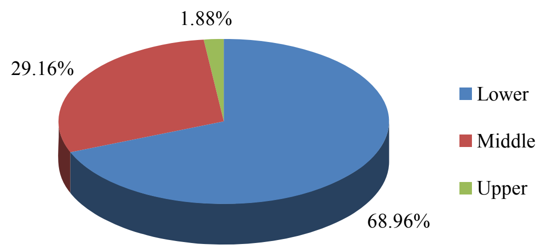

Fig. 7 Percentage density of trees in lower, middle and upper storey

Table 4. Density, species number and individuals to species ratios by storey

Storey	Height (m)	Stem		Species		Ratio of individuals to species
		Density	Percentage (%)	No.	Percentage (%)	
Lower	2.5-13.33	657.07	69	34	94.44	19.3:1
Middle	13.33<H<26.66	277.83	29	28	77.77	10.0:1
Upper	>26.66	17.92	2	9	25.00	2.0:1

The middle layer of Komto Forest was occupied by species including *Syzygium guieneense* ssp. *afromontanum, Allophylus abyssinicus*, *Albizia gummifera*, *Albizia schimperiana*, *Teclea nobilis*, *Vepris dainellii*, *Olea capensis* ssp. *macrocarpa*, *Canthium oligocarpum*, *Millettia ferruginea*, *Olea welwitschii*. The

lower storey was largely dominated by shrubs and small trees such as *Rytigynia neglecta*, *Erytrococca trichogyne*, *Clausena anisata*, *Chionanthus mildbraedii*, *Dombeya torrida*, *Flacourtia indica*, *Psychotria orophila*.

The highest proportion of species was concentrated in the lower storey (94.44%) followed by the middle (69.44%) and upper storey (36.11%), (Table 4). A similar result was observed by Kelbessa and Soromessa (2008) in Bonga Forest.

Importance value index

Species with lower IVI values need high conservation efforts while those with higher IVI values need monitoring management. IVIs for 36 species are listed in Table 5. *Syzygium guineense* ssp. *afromontanum*, *Croton macrostachyus*, *Ficus sur*, *Allophylus abyssinicus*, *Apodites dimidiata*, *Rytigynia neglecta* and *Pouteria adolfi-friederici* had the highest IVI values (Table 5). This is because of their low demand by the local people for timber and other construction material. These seven species contributed about 50% of the total importance values whereas the remaining woody species (80.56%) had combined IVI values of about 50%. In addition, Myrtaceae, a family with single species *Syzygium guineense* ssp. *afromontanum*, was the most important family in the Forest (Table 5).

Density, frequency and dominance

Rytigynia neglecta, *Syzygium guineense* ssp. *afromontanum*, *Pouteria adolfi-friederici* and *Croton macrostachyus* were the four most abundant species, accounting for 29.7% of total density (Table 5). *Syzygium guineense* ssp. *afromontanum*, *Croton macrostachyus*, *Allophylus abyssinicus* and *Rytigynia neglecta* were recorded at highest frequently (Table 5). Most species were in the lower IVI classes (Fig. 8).

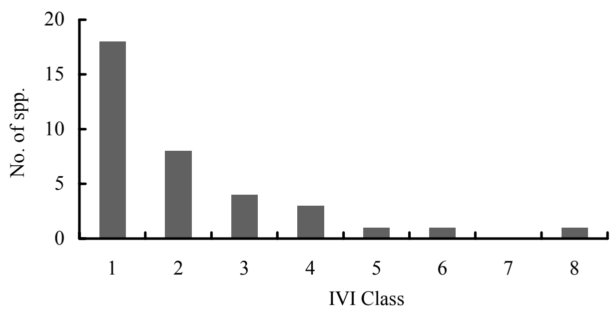

Fig. 8 Number of species by IVI class in Komto Forest (IVI classes 1 stands for 0–5, 2 stands for 5.1–10.0, 3 stands for 10.1–15.0, 4 stands for 15.1–20.0, 5 stands for 20.1–25.0, 6 stands for 25.1–30.0, 7 stands for 30.1–35.0 and 8 stands for 35.1 and above)

Population structure

The pattern of diameter class distribution indicates the general trend of population dynamics and recruitment processes of a species. Analysis of the population structure of 36 tree species revealed four general patterns (Fig. 9A-D). The total seedling, sapling, and mature woody tree densities of 36 selected tree and shrub species were about 1888, 897, and 953 individuals per hectare respectively (Table 6).

Table 5. Importance Value Index (IVI) of the dominant tree species of Komto forest

Species	R_D	R_{DO}	R_F	I_{VI}
Syzygium guineense ssp. *afromontanum*	7.77	21.5	6.41	35.67
Croton macrostachyus	6.78	12.54	6.41	25.73
Ficus sur	4.55	16.6	3.12	24.26
Allophylus abyssinicus	5.84	4.5	6.08	16.41
Apodytes dimidiata	3.91	6.90	4.60	15.39
Rytigynia neglecta	9.31	0.22	5.75	15.28
Pouteria adolfi-friedrici	6.83	4.10	3.94	14.87
Prunus africana	2.92	6.66	2.63	12.21
Bersama abyssinica	5.30	1.30	5.43	12.01
Erytrococca trichogyne	5.49	0.20	4.44	10.13
Albizia schimperiana	1.98	4.83	2.46	9.27
Vepris dainellii	2.72	1.14	5.26	9.12
Maesa lanceolata	3.27	1.62	4.09	8.98
Teclea nobilis	2.37	0.92	5.09	8.38
Clausena anisata	4.31	0.07	3.31	7.69
Albizia gummifera	1.88	2.90	1.80	6.58
Euphorbia ampliphylla	1.63	4.02	0.82	6.47
Pittosporum viridiflorum	2.62	0.41	2.30	5.33
Maytenus undata	2.82	0.20	1.97	4.96
Dombeya torrida	1.88	0.10	2.79	4.76
Psychotria orophila	2.18	0.30	2.26	4.71
Ekebergia capensis	0.54	2.56	1.48	4.58
Macaranga capensis	0.94	1.71	1.31	3.96
Olea welwitschii	1.98	0.26	1.48	3.72
Canthium oligocarpum	1.29	0.31	1.97	3.57
Vernonia amygdalina	1.33	0.14	1.83	3.30
Celtis africana	1.73	0.63	0.69	3.05
Chionanthus mildbraedii	1.29	0.07	1.64	2.997
Cassiporea malosana	1.23	0.08	1.64	2.95
Calpurnia aurea	0.74	0.12	1.97	2.83
Schefflera abyssinica	0.19	1.42	0.65	2.26
Olea capensis ssp. *macrocarpa*	0.69	0.08	1.31	2.08
Flacourtia indica	0.59	0.03	1.15	1.765
Millettia ferruginea	0.69	0.15	0.61	1.45
Ritchiea albersii	0.19	0.30	0.49	0.96
Hagenia abyssinca	0.15	0.43	0.33	0.91
Total	100.00	100.00	100.00	

Notes: R_F is Relative Frequency, R_D is Relative Density and R_{DO} is Relative Dominance I_{VI} is Important Value Index.

Regeneration Status of Komto Forest

The composition, distribution and density of seedlings (SE) and saplings (SA) are indicators of the future regeneration status of any forest. The distribution of seedlings, saplings and mature trees/shrubs shows three distinct patterns (Fig. 10 a–j). The first group includes species represented by all three stages, the second group includes seedling and mature trees/shrubs but no saplings

(Fig. 10 i & j). The third group of species includes only mature trees/shrubs (Fig. 10 e & f).

Table 6. Selected tree species with their seedling, sapling and mature tree density per hectare

Species	Seedling	Sapling	Ratio of Mature Tree to Shrub	Sum of Densities
Albizia gummifera	107	32	18	157
Albizia schimperiana	87	56	20	163
Allophylus abyssinicus	157	103	55.6	315.6
Apodytes dimidiata	25	15	37.3	77.3
Bersama abyssinica	12	3	50.5	65.5
Celtis africana	15	6	16.5	37.5
Cassiporia malosana	38	21	7.07	66.07
Chionanthus mildbraedii	58	23	12.26	93.26
Canthium oligocarpum	56	13	12.26	81.26
Calpurnia aurea	24	0	11.8	35.8
Clausena anisata	36	12	41.04	89.04
Croton macrostachyus	51	43	64.62	158.62
Dombeya torrida	35	14	18	67
Ekebergia capensis	0	0	5.19	5.19
Erytrococca trichogyne	37	12	52.36	101.36
Euphorbia ampliphylla	3	0	15.56	18.56
Flacourtia indica	0	0	5.66	5.66
Ficus sur	14	5	43.4	62.4
Hagenia abyssinca	0	0	1.5	1.5
Macaranga capensis	0	0	9	9
Maytenus undata	25	5	26.9	56.9
Maesa lanceolata	43	20	31.13	94.13
Millettia ferruginea	13	0	6.6	19.6
Olea capensis ssp. *macrocarpa*	34	0	6.6	40.6
Olea welwitschii	19	0	18.8	37.8
Psycotria orophila	55	45	20	120
Pittosporum viridiflorum	78	36	25	139
Pouteria adolfi-friederici	125	56	65.1	246.1
Prunus africana	69	54	27.8	150.8
Ritchiea albersii	0	0	2.0	2
Rytigynia neglecta	98	74	88.7	260.7
Schefflera abyssinica	0	0	2.0	2
Syzygium guineense ssp. *afromontanum*	67	40	74.05	181.05
Teclea nobilis	140	58	22.6	220.6
Vernonia amygdalina	0	0	12.7	12.7
Vepris dainellii	367	151	26	544
Total (individuals·ha^{-1})	1888	897	952.83	3737.83

Seven species (19.44%) were not represented by both seedlings and saplings (Table 7), and only a few mature individuals were recorded for these species (Table 6). On the other hand, 5 species (13.88%) of the total were not represented by saplings (Table 6).

Based on these results, tree species were grouped into 3 priority classes for conservation. These are class 1 with no seedlings or saplings, Class 2 with seedlings but no saplings, and Class 3 with both seedlings and saplings ≥ 1 individual·ha^{-1} (Table 7).

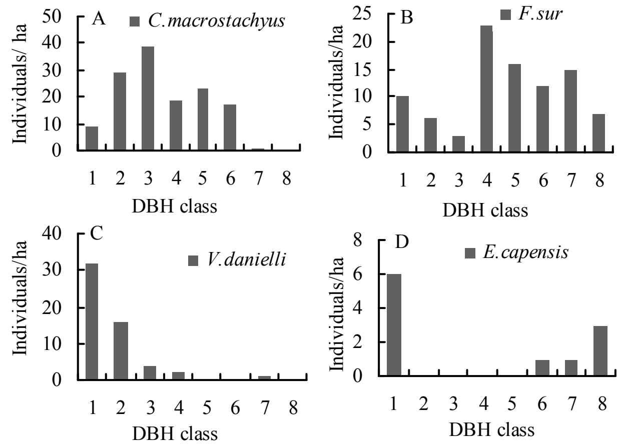

Fig. 9 Population structure of selected tree species (Tree species are classified according to different DBH classes, such as, 1 stands for 2.6−12.0 cm of DBH, 2 stands for 12.1−22.0 cm of DBH, 3 stands for 22.1−32.0 cm of DBH, 4 stands for 32.1−42.0 cm of DBH, 5 stands for 42.1−52.0 cm of DBH, 6 stands for 52.1−62.0 cm of DBH, 7 stands for 62.1−72.0 cm of DBH and 8 stands for≥72.0 cm of DBH).

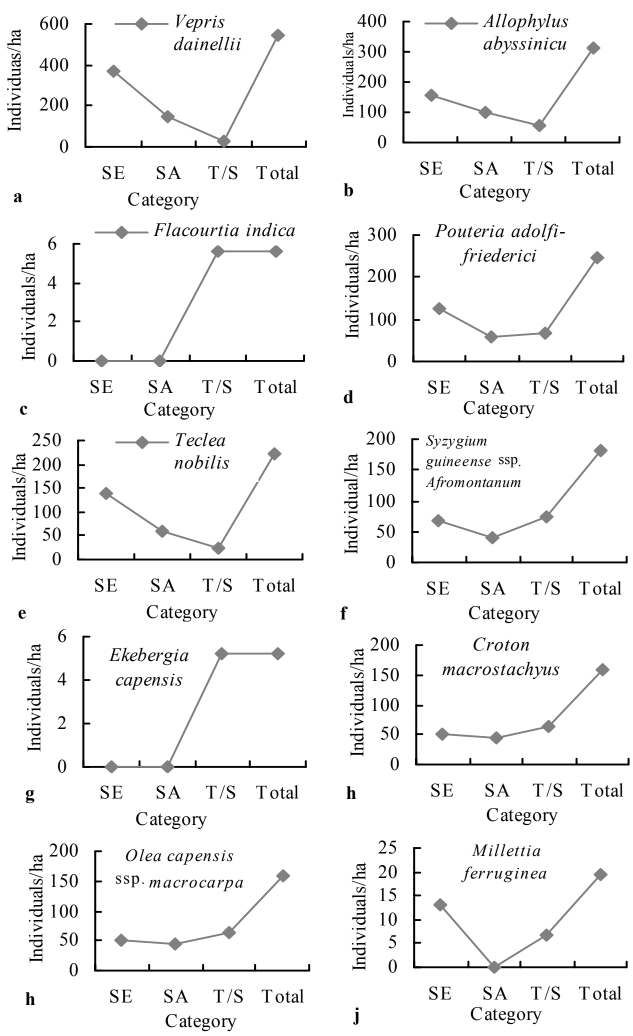

Fig. 10 (a-j). Seedlings, saplings and tree/shrub distribution of some selected species occurring in Komto Forest

Table 7. Species conservation priority classes

Priority class 1	Priority class 2	Priority class 3		
Hagenia abyssinica	*Millettia ferruginia*	*Vepris dainellii*	*Celtis africana*	*Bersama abyssinca*
Ritchiea albersi	*Olea welwitschii*	*Teclea nobilis*	*Maytenus undata*	*Albizia schimperiana*
Schefflera abyssinica	*Olea capensis* ssp. *macrocarpa*	*Croton macrostachyus*	*Ficus sur*	*Albizia gummifera*
Macaranga cpensis	*Calpurnia aurea*	*Apodytes dimidiata*	*Cassiporia malosana*	*Chionanthus mildbraedii*
Ekebergia capensis	*Euphorbia ampliphylla*	*Allophylus abyssinicus*	*Dombeya torrida*	*Clausena anisata*
Vernonia amygdalina	-	*Pouteria adolfi-friederici*	*Canthium oligocarpum*	*Maesa lanceolata*
Flacourtia indica	-	*Prunus africana*	*Pittosporum viridiflorum*	*Rytigynia neglecta*
-	-	-	-	*Syzygium guineense* ssp. *afromontanum*

Discussion

Structural description in Komto Forest

Results of the structural analysis of the natural vegetation of Komto Forest indicated that the proportion of medium-sized plants (DBH between 10 and 20 cm) was greater than for large plants (DBH $\geq$ 20 cm) but the medium: large ratio was lower than for other forests (Alata-Bolale, Menagesha Suba, Chilimo and Masha Anderacha) but larger than Dodola Forest (Table 2). The proportion of small plants (DBH<10 cm) was much greater (42.82%) although the above ratio is lower (Table 1), indicating that Komto Forest is in a stage of secondary regeneration.

Size class distribution

Distribution of individuals in different height and DBH classes indicated an inverted J-shaped curve with most individuals in lower size classes (Fig 3, 4). This could be attributed to a high rate of regeneration but poor recruitment. Senbeta and Teketay (2003) also concluded that the dominance of shrubs and small trees in a forest suggests that bigger tree species are selectively removed. The frequency distribution of individuals in the different size classes in Komto Forest, however, was not uniform. The number was lower at DBH class 3 (Fig. 4). This might be due to selective cutting of individuals at this DBH.

The total basal area calculated for Komto Forest was 50.72 $m^2 \cdot ha^{-1}$, of which more than 21.47% (10.89 $m^2 \cdot ha^{-1}$) was contributed by *Syzygium guineense* ssp. *afromontanum* (Table 5). The predominance of this species in the Forest was probably because of the low market demand of its timber. *Syzygium guineense* ssp. *afromontanum* was also the dominant species in the Belete forest for a similar reason (Kitessa et al. 2008). Few large plants contributed a disproportionally large share of the total basal area (Table 3). Similar results were observed in the contribution of the different DBH classes to the basal area in other forests in Ethiopia as in Masha Anderacha Forest (Yeshitela and Bekele. 2003), Dodola Forest (Hundera et al. 2007), and Belete Forest (Kitessa et al. 2008).

Dominant species of Komto Forest

Dominant species for Komto Forest were identified based on their rank in IVI value (Table 5). Species with IVI value above 5.00 are referred to as dominant because of their abundance and large basal area. Accordingly, *Syzygium guineense* ssp. *afromontanum*, *Croton macrostachyus*, *Ficus sur*, *Allophylus abyssinicus*, *Apodytes dimidiata*, *Rytigynia neglecta*, *Pouteria adolfi-friederici*, *Prunus africana*, *Bersama abyssinica*, *Erytrococca trychogyne*, *Albizia schimperiana*, *Vepris dainellii*, *Maesa lanceolata*, *Teclea nobilis*, *Clausena anisata*, *Albizia gummifera*, *Euphorbia ampliphylla* and *Pittosporum viridiflorum* were identified as dominant species.

Population structure

Analysis of the population of 36 forest tree species revealed four general patterns (Fig. 9). The first pattern was a bell-shaped distribution formed by species with high numbers of individuals in the middle DBH classes (Fig. 9A). Species such as *Croton macrostachyus* and *Syzygium guineense* ssp. *afromontanum* were characterized by this distribution pattern. This pattern indicates poor reproduction and recruitment, which may be associated with intense competition from surrounding trees. Senbeta et al. (2007) and Woldeyohannes (2008) reported similar reasons for a bell-shaped population structure.

The second pattern was formed by species with positively skewed distributions (inverted J-curve). These species had the highest density in lower DBH classes with gradual declines in density towards the bigger classes, suggesting good reproduction and healthy regeneration potential (Fig. 9B). *Vepris dainellii*, *Teclea nobilis*, *Canthium oligocarpum*, *Bersama abyssinica, Cassipourea malosana*, *Maesa lanceolata,* and *Apodites dimidiata* had inverted J-curve population structure.

The third pattern (Fig. 9C) was formed by species having irregular distributions over diameter classes. Some diameter classes (DBH classes 2, 3 and 8) were poorly represented indicating selective removal of these classes while other diameter classes (DBH classes 4, 5 and 7) were well represented. The following species had this type of population pattern: *Albizia schimperiana*, *Albizia gummifera*, *Allophylus abyssinicus*, *Euphorbia ampliphylla*, *Ficus sur,* and *Macaranga capensis*.

The fourth pattern was a U-shaped curve (Fig. 9D) formed by species with few or no individuals in the middle DBH classes and represented only by the lower and higher DBH classes. Species with this type of population structure were *Prunus africana*, *Pouteria adolfi-friederici* and *Ekebergia capensis*. The interme-

diate diameter classes might have been poorly represented due to selective removal of medium sized plants. For example, many stumps of *Pouteria adolfi-friederici*, a very important timber tree species in the area, were observed, suggesting a further risk of removal of the remaining individuals.

Generally, an inverted J-shaped distribution was exhibited by some tree species representing a healthy regeneration (Fig. 9B). On the other hand, other distribution patterns such as bell-shaped, irregular and U-shaped (Fig. 9A, C and D) were also observed. Most of the species with irregular distributions were trees that are hunted by the local people. For example, *Prunus africana* at its medium size is needed for construction (personal communication with the local people and personal observation). The complete absence of individuals in some diameter classes indicates tree mortality caused by trampling by livestock or selective cutting for construction, timber or firewood purposes.

Regeneration status of Komto Forest

Explanations for insufficient seedlings and saplings of some tree species (in priority classes 1 and 2) in the forest could be many, including seed predation, grazing and browsing, lack of safe sites for seed recruitment, or the need of dormancy period for seeds of certain trees. In addition, litter accumulation, pathogens, moisture stress, and possession of alternative adaptations for propagation other than seed germination could also be the cause for lack of sufficient seedlings. Similar findings were also reported by Denu (2006), Shibru and Balcha (2004).

Generally, *Vepris dainellii*, *Teclea nobilis*, *Croton macrostachyus*, *Apodytes dimidiata,* and *Allophylus abyssinicus* were represented by both seedlings and saplings, and had relatively high regeneration rates. Others such as *Hagenia abyssinica*, *Ritchiea albersii*, *Schefflera abyssinica*, *Macaranga capensis*, *Ekebergia capensis*, *Vernonia amygdalina,* and *Flacourtia indica* had no saplings and, therefore, lower regeneration status. We suggest that these species are under threat of local extinction. Species under these priority classes, therefore, need due attention in order to save them from local extinction.

Conclusion and recommendation

We recorded 103 woody plant species representing 87 genera and 45 families. Structural description of the forest indicated the predominance of small trees and shrubs, suggesting that Komto Forest is in a stage of secondary regeneration. In addition, the density of woody species (trees, shrubs and lianas) in Komto Forest declined with increasing DBH and height classes (high-density of trees and shrubs in the lower classes) implying good recruitment. The total basal area for Komto Forest was 50.72 $m^2 \cdot ha^{-1}$, but most of the basal area was contributed by a few large plants. Analysis of population structure of most common species of trees and shrubs revealed different patterns of population structure, indicating high variation among species population dynamics within the forest. We observed four population patterns (bell shaped, inverted J-shaped, irregular and U-shaped).

In terms of regeneration, seven species had no seedlings or saplings, five tree species had no saplings, and all other species were represented by all stages (seedlings, saplings and mature plants). Based on this result, we grouped the woody species of Komto Forest into three priority classes for conservation. Komto Forest affords great economic and social value for the local rural communities as a source of both timber and non-timber forest products. To ease the present human influence on the natural forest, and for future management of the forest on a sustainable basis, we offer the following recommendations:

Participatory forest management programs should be introduced and implemented so that local communities assume responsibility for management and conservation of the forest and become beneficiaries of the economic payback derived from this activity.

Species in the first and second priority classes for conservation should be given appropriate attention and should be conserved in-situ (in their natural habitat) through the collaboration of local communities with the District Agriculture and Rural Development Office and other interested individuals and stakeholders; and further investigation should be carried out to identify the reasons for the absence of regeneration.

Creating public awareness, through extension programs, on the multiple uses of forest resources and ecosystems is essential to safeguard the biodiversity of the Forest.

Carry out further investigation on the patterns of ecosystem functioning, soil seed banks, germination performance of seeds, establishment of seedlings, and studies on the role of gap dynamics for suggested species.

The management strategy should focus on a multiple-use conservation approach. For example, undisturbed areas of the forest can be designated for strict conservation so that they may act as repositories of biodiversity and possibly as a source of forest genetic resources, while peripheral areas could be utilized on a sustainable basis.

To promote the sustainable use of the forest and its products, ethnobotanical studies and exploration of indigenous knowledge on the diverse uses of plants should be carried out.

The planning and management of the Forest should be assisted by research findings, such as detailed ecological studies in relation to various environmental factors such as soil type and properties. More basic and applied researches should be promoted.

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Appendix I. List of woody species collected from Komto Forest (2009)

Item No.	Scientific name	Family	Vernacular name (Afaan Oromoo)
1	*Abutilon figarianum* Webb.	Malvaceae	
2	*Abutilon longicuspe* Hochest. ex A.Rich.	Malvaceae	Hincinnii adii
3	*Abutilon maurtianum* (Jacq.) Medie.	Malvaceae	Qaqaroo
4	*Acalypha ornata* A.Rich.	Euphorbiaceae	Gurgubbee Qamalee
5	*Acanthus eminens* C.B.Clarke	Acanthaceae	Kosorruu
6	*Albizia gummifera* (J.F.Gmel.) C.A.Sim.	Fabaceae	Hambabbeessa
7	*Albizia schimperiana* Oliv.	Fabaceae	Muka arbaa
8	*Alectra sessiliflora* (Vahl) Kuntze	Scrophulariaceae	
9	*Allophylus abyssinicus* (Hochst.) Radlk.	Sapindaceae	Malqaqqoo
10	*Apodytes dimidiata* E.Mey.ex Arn	Icancinaceae	Wandabiyoo
11	*Asparagus africanus* Lam.	Asparagaceae	Sariitii
12	*Bersama abyssinica* Fresen.	Melianthaceae	Loshiisaa/Araarsaa
13	*Brucea antidysenterica* J.F.Mill.	Simaroubaceae	Qomonyoo
14	*Buddleja polystachya* Fresen.	Loganiaceae	Hamfaaree
15	*Calpurnia aurea* (Ait.) Benth.	Fabaceae	Ceekaa
16	*Canthium oligocarpum* Hiern	Rubiaceae	Mixoo qeerramsaa
17	*Cassipourea malosana* (Baker) Alston	Rhizophoraceae	Xiilloo
18	*Celtis africana* Burm.f.	Ulmaceae	Cayii
19	*Ceropegia sobolifera* N.E.Br.	Asclepiadaceae	
20	*Chionanthus mildbraedii* (Gilg & Schellenb.) Stearn	Oleaceae	Karra waayyuu
21	*Clausena anisata* (Willd.) Benth.	Rutaceae	Ulumaayii
22	*Clematis simensis* Fresen.	Ranunculaceae	Hidda fiitii
23	*Clerodendrum myricoides* (Hochst.) Vatke	Lamiaceae	
24	*Combretum paniculatum* Vent.	Combretaceae	Hidda Baggee
25	*Crotalaria rosenii* (Pax) Milne-Redh ex Polhill	Fabaceae	
26	*Crotalaria mildbraedii* Bak.f.	Fabaceae	Atarii waraabessaa
27	*Croton macrostachyus* Del.	Euphorbiaceae	Bakkanniisa
28	*Cyphostemma adenocaule* (Steud. ex A.Rich.) Desc. ex Wild & Drummond	Vitaceae	Hidda Reeffaa
29	*Dalbergia lactea* Vatke	Fabaceae	Ajjagnoo
30	*Dombeya torrida* (J.F.Gmel.) P. Bamps	Sterculiaceae	Daannisa
31	*Dracaena afromontana* Mildbr.	Dracaenaceae	Afarfattuu
32	*Dracaena steudneri* Engl.	Dracaenaceae	Warqee Qamalee guddaa
33	*Dregea schimperi* (Decne.) Bullock	Asclepiadaceae	Hidda goorri'saa
34	*Ekebergia capensis* Sparrm.	Meliaceae	Somboo
35	*Embelia schimperi* Vatke	Myrsinaceae	Haanquu
36	*Erythrina brucei* Schweinf.	Fabaceae	Waleensuu
37	*Erythrococca trichogyne* (Muell Arg.) Prain	Euphorbiaceae	Caakkoo
38	*Euphorbia ampliphylla* Pax	Euphorbiaceae	Adaamii
39	*Ficus ovata* Vahl	Moraceae	Qilimxoo
40	*Ficus sur* Forssk.	Moraceae	Harbuu
41	*Flacourtia indica* (Burm.f) Merr.	Flacourtiaceae	Akuukkuu
42	*Galiniera saxifraga* (Hochst.) Bridson	Rubiaceae	
43	*Gouania longispicata* Engl.	Rhamnaceae	
44	*Grewia ferruginea* Hochst. ex A.Rich.	Tliaceae	Dhoqonuu
45	*Hagenia abyssinica* (Bruce) J.F.Gmel.	Rosaceae	Heexoo
46	*Hibiscus macranthus* Hochest.ex A.Rich	Malvaceae	Hincinnii Qarancaa
47	*Hippocratea africana* (Willd.) Loes.	Celastraceae	Hidda Xiyoo
48	*Hippocratea goetzei* Loes.	Celastraceae	Hidda gafarsaa
49	*Indigofera arrecta* Hochst. ex A.Rich.	Fabaceae	Heennaa
50	*Jasminum abyssinicum* Hochst. ex DC.	Oleaceae	Hidda Ichilbee
51	*Justicia schimperiana* (Hochst. ex Nees) T. Anders.	Acanthaceae	Dhummuugaa

Continued **Appendix I.**

Item No.	Scientific name	Family	Vernacular name (Afaan Oromoo)
52	*Kosteletzkya adoensis* (Hochest.ex A.Rich.) Mast.	Malvaceae	Hincinnii
53	*Landolphia buchananii* (Hall.f.) Stapf	Apocynaceae	Hidda geeboo
54	*Lepidotrichilia volkensii (Gurke) Leroy*	Meliaceae	
55	*Leptadenia arborea* (Forssk.) Schweinf.	Asclepiadaceae	
56	*Lippia adoensis* Hchest. ex Walp.	Verbenaceae	Kusaayee
57	*Macaranga capensis* (Baill.) Sim	Euphorbiaceae	Doggomaa
58	*Maesa lanceolata* Forssk.	Myrsinaceae	Abbayyii
59	*Maytenus addat* (Loes.) Sebsebe	Celastraceae	Kombosha
60	*Maytenus gracilipes* (Welw. ex Oliv.) Exell ssp.*arguta* (Loes.) Sebsebe	Celastraceae	Hacaacii
61	*Maytenus obscura* (A.Rich.) Cuf.	Celastraceae	Kombosha
62	*Maytenus undata* (Thunb.) Blakelock	Celastraceae	Ilikkee
63	*Millettia ferruginea* ssp *.ferruginea* (Hochst.) Bak.	Fabaceae	Sootalloo
64	*Nesphostylis holosericea* (Bak.) Verdc.	Fabaceae	
65	*Nuxia congesta* R.Br.ex Fresen.	Loganiaceae	Naforoo
66	*Ocimum lamiifolium* Hochst.ex Benth.	Lamiaceae	Hancabbii
67	*Olea capensis* L. ssp *macrocarpa* (C.A.Wright.) Verdc.	Oleaceae	Gagamaa
68	*Olea welwitschii* (Knobl.) Gilg & Schellenb.	Oleaceae	Gajjaa
69	*Pavonia kilimandscharica* Gurke	Malvaceae	
70	*Periploca linearifolia* Quart-Dill. & A.Rich.	Asclepiadaceae	Hidda aannolee
71	*Phragmanthera macrosolen* (A.Rich.) M.Gilbert	Loranthaceae	Dheertuu
72	*Physalis peruviana* L.	Solanaceae	
73	*Phytolacca dodecandra* L'Herit.	Phytolaccaceae	Handoodee
74	*Pittosporum viridiflorum* Sims	Pittosporaceae	Qassammee
75	*Pouteria adolfi-friederici* (Engl.) Baehni	Sapotaceae	Sooqee
76	*Premna schimperi* Engl.	Lamiaceae	Urgeessaa
77	*Prunus africana* (Hook.f.) Kalkm	Rosaceae	Hoomii
78	*Psychotria orophila* Petit	Rubiaceae	
79	*Pterolobium stellatum* (Forssk.) Brenan	Fabaceae	Harangamaa
80	*Rhamnus prinoides* L'Herit.	Rhamnaceae	Geeshoo
81	*Rhus glutinosa* A.Rich.	Anacardiaceae	Xaaxessaa
82	*Ritchiea albersii* Gilg	Capparidaceae	
83	*Rubus apetalus* Poir.	Rosaceae	Goraa arbaa
84	*Rubus steudneri* Schweinf.	Rosaceae	Goraa
85	*Rytigynia neglecta* (Hiern) Robyns	Rubiaceae	Mixoo
86	*Schefflera abyssinica* (Hochst.ex A.Rich.) Harms	Araliaceae	Gatamaa
87	*Senna petersiana* (Bolle) Lock	Fabaceae	Raamsoo
88	*Sida rhombifolia* L.	Malvaceae	
89	*Sida schimperiana* Hochst. ex A.Rich.	Malvaceae	Kottee harree
90	*Solanecio gigas* (Vatke) C.Jeffrey	Asteraceae	Jilma Jaldeessaa
91	*Solanum anguivi* Lam.	Solanaceae	Hiddii saree
92	*Solanum incanum* L.	Solanaceae	Hiddii loonii
93	*Solanum marginatum* L.f.	Solanaceae	Hiddii hongorcaa
94	*Sparmannia ricinocarpa* (Eckl. & Zeyh.) O.Ktze.	Tliaceae	
95	*Syzygium guineense* (Willd.) DC. ssp. *afromontanum* F.White	Myrtaceae	Baddeessaa
96	*Teclea nobilis* Del.	Rutaceae	Hadheessa
97	*Tiliacora troupinii* Cufod.	Menispermaceae	Hidda Liqixii
98	*Triumfetta rhomboidea* Jacq.	Tliaceae	Hincinnii lagaa
99	*Urera hypselodendron* (A.Rich.) Wedd.	Urticaceae	Laanqisaa
100	*Vepris dainellii* (Pic-Serm.) Kokwaro	Rutaceae	Hadheessa
101	*Vernonia amygdalina* Del.	Asteraceae	Eebicha
102	*Vernonia auriculifera* Hiern	Asteraceae	Reejjii
103	*Vernonia leopoldi* (Sch.Bip.ex Walp.)Vatke	Asteraceae	Sooyyoma